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Basic Principles of Genetics for Pork Producers

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Organized swine testing dates back to 1929 in Canada. Evaluation of breeding stock was primarily subject[illegible] 1967 when the Ontario ROP (Record of Performance, [illegible] Testing Program was initiated. Its purpose is to enable seedstock and commercial pork producers to performance test potential breeding stock for backfat thickness and rate of gain and thus evaluate them objectively. Home-tested boars and gilts are weighed and backfat probed, and given an index based on these figures adjusted to a standard weight of 90 kg. The index compares the individual animal's performance for backfat and days to 90 kg with the herd average for pigs of the same breed and sex. In addition, boars from different herds are station-tested together to compare their genetic potential. Whereas the home-test only allows accurate comparisons within a herd, the station-test allows accurate comparisons across herds. The test station index compares the performance of each boar with the average performance of the entire group tested in the same wing (four isolated sections) at the same time. Although the test station allows across herd comparisons, it is limited in the number of boars that can be tested each year (approximately 1500 or 10% of all tested boars), and therefore in the amount of genetic progress that can be realized through use of the test station alone. In order to be effective, the test station must complement home-testing of boars and gilts.

The development of a new genetic evaluation system for swine allows accurate genetic comparisons across herds for home and station-tested boars and gilts. The Canadian Swine Genetic Evaluation Program provides Estimated Breeding Values for all ROP-tested boars and sows. Estimated Breeding Values predict the "genetic merit" of an individual animal, or that part of its performance that will be passed on to its offspring. Estimated Breeding Values are able to predict genetic merit because they take into account all records on the animal's relatives (i.e. the performance of its sire, dam, grandsire, granddam, littermates, progeny, etc.). By including records on all relatives the probability of selecting a genetically superior animal is greatly increased. Superior performance that is consistently demonstrated in a number of related animals is largely due to genetic superiority.

Valid comparisons of breeding stock in different herds are also possible with Estimated Breeding Values. The effect of management and environment on an animal's performance can be removed, leaving only the effect of genetics. Essentially, all straightbred pigs of the same breed can be compared, regardless of the herd they were raised in (and therefore the management and environment they were exposed to). Superior performance, then, is due to genetics, not a favorable environment.

The Canadian Swine Genetic Evaluation Program is a highly advanced method of identifying superior breeding stock. Its development allows breeders to make accurate selection decisions which can result in increased rates of genetic improvement for the entire industry. The new system will not guarantee genetic progress – a well designed breeding program is equally if not more important. In order to plan an effective breeding program, it is necessary to have a thorough understanding of the basic principles of genetics.

Following is some basic terminology producers should be familiar with:

SELECTION

The process whereby certain animals are chosen to become breeding animals and parents of the next generation. Selection will not introduce new genes into the herd, it simply increases or decreases their frequency. The object of selection is to increase the frequency of desirable genes.

Breeding stock should be selected for traits of economic importance.

CULLING

The process whereby certain existing breeding animals are not permitted to be parents of the next generation. Breeding stock that do not meet specified standards are removed from the breeding herd and marketed.

REPLACEMENT RATE

The percentage of breeding animals that are removed or culled from the herd and subsequently replaced each year. Producers should aim to replace at least 30 to 35% of their sows each year. Many producers maintain higher replacement rates (up to 50%). This will result in greater genetic progress (provided that the replacement gilt being selected is genetically superior to the sow she is replacing), but will also result in a younger herd with lower productivity and less overall immunity to diseases that may be present.

Regular replacement of herd boars is essential for maximum genetic progress since their influence is widespread

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across the herd. If a boar is mated to 20 sows, he contributes 50% of the genes to all his offspring while each sows contribution is only 2.5% (Figure 1). Purchasing young boars is important for two reasons: First, young boars are (or should be) genetically superior to the older boar they are replacing; and second, they are often necessary for breeding young gilts, as older boars are often too large. Older boars should be culled if suitable replacement young boars with superior estimated breeding values are available.

Figure 1 Contribution of Boar and Sow to the Genetic Make-Up of Their Litters

BOAR:SOW RATIO = 1:20

Assume that a boar is mated to twenty sows

Genetically, contribution to an individual litter is:
Boar 50%
Sow 50%

Genetically, contribution to all 20 litters is:

	# litters	contribution to each	total contribution
Boar	20/20	50%	50%
Sow	1/20	50%	2.5%

TRAITS OF IMPORTANCE

Improvement of traits of economic importance will result in additional profit. Effective breeding programs must be based on selection for economically important traits which contribute to net merit (Figure 2). Economic traits can be classified into the following categories, and various measures used to describe them:

(1) reproductive efficiency
(2) production efficiency
(3) product merit

Reproductive efficiency can be defined as the capacity of an animal to produce an abundance of offspring with a high rate of survival. Commonly measured components of reproductive efficiency include conception rate, farrowing rate, number of pigs born per litter (per year) and percent mortality. Production efficiency involves an output/input relationship or the amount of production per unit of input. Important measures used to define production efficiency are growth rate, backfat thickness and feed efficiency. Product merit is defined as the net merit of the product produced and is most commonly measured as carcass index.

Ideally, all traits of economic importance should be considered when selecting replacement breeding stock. Genetic progress for any one trait will decrease as the number of traits selected for increases. It is necessary to determine how readily the trait can be improved by selection and how much profit can be realized by its improvement. Decisions must be made, and although trade-offs are sometimes necessary, one trait should not be selected at the expense of causing an undesirable effect on another economically important trait (see genetic and phenotypic correlation).

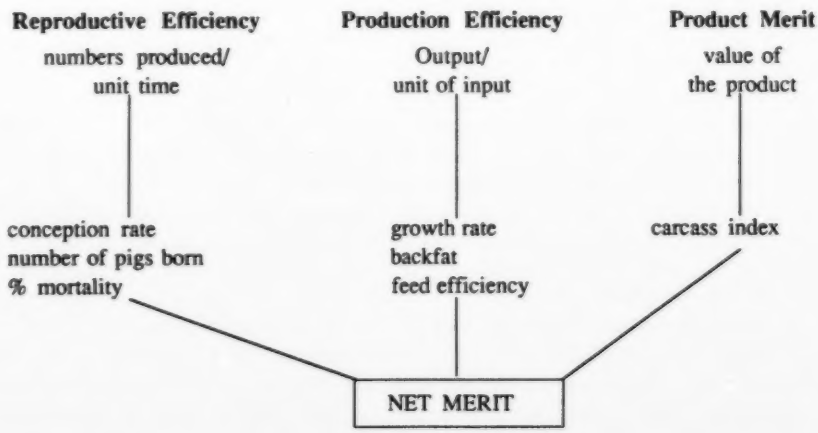
Often sire (male) lines are selected for performance traits, while dam (female) lines are selected for reproductive traits.

HERITABILITY (h^2)

That part of a trait's expression that is due to inheritance or genetics. Theoretically, h^2 can range from 0 to 1.0, (0 to 100%) but most traits fall in the range of 0.1 to 0.5 (10% to 50%). That part of a trait's expression that is not due to genetics is caused by the environment (management). If a trait has a heritability of 0.3 (30%), then 30% of the traits expression is expected to be due to genetics, and 70% is due to environment.

Traits are classified as low, medium or high heritability according to their degree of inheritance. Generally, traits are classified as follows: reproductive traits – low, performance traits – medium, and carcass traits – high. Traits of high and

Figure 2 Economically Important Traits in Swine Production



medium heritability are more responsive to selection than traits of low heritability. The latter are more readily improved through management. Heritabilities of economically important traits are given in Table 1.

Table 1 Heritabilities of Economically Important Traits

REPRODUCTIVE TRAITS	h^2 (%)
Litter size at birth	10%
Litter birth weight	10%
Litter weaning weight	15%
PRODUCTION TRAITS	
Growth rate	30%
Feed Conversion	30%
CARCASS TRAITS	
Backfat thickness	40-50%
Loin-eye area	50%

SELECTION DIFFERENTIAL

The difference between the average performance of the selected animals and the average performance of the entire group from which they were chosen (Table 2). The actual "intensity of selection" can be determined if the selection differential and the variation (see variance) are known. Selection intensity increases as the fraction of tested animals kept for breeding purposes decreases. Intensity of selection is greater for boars than gilts, since fewer boars are needed for breeding purposes.

Table 2 Calculation of Selection Differential–Days to 90 Kg

Select top 5% of boars:
- average of selected boars 132 days
- overall herd average 158 days
- selection differential (158-132) = 26 days

Select top 40% of gilts:
- average of selected gilts 146 days
- overall herd average 158 days
- selection differential (158-146) 12 days

***note that as the percentage of animals selected increases, the selection differential decreases.*

VARIANCE

The amount of variation for a particular trait within a population (herd). Animals can differ (in performance or appearance) because of their genetic make-up or their environment or a combination of the two. Variation is essential – otherwise all animals would be identical and selection would not result in any improvement. The idea is to have enough variation (the difference between the top and bottom animals) so that selection will improve average performance in the herd.

GENERATION INTERVAL

The average age of a sow or boar when their replacement progeny are born. In otherwords, the length of time between generations. This is limited to a certain extent by puberty, but is also greatly influenced by management and culling practices in the herd.

GENETIC PROGRESS

The amount of improvement due to genetics. Genetic progress per generation is dependent on the amount of genetic variation in the trait being selected, the intensity of selection and the accuracy of selection. Genetic progress per year is determined also by the generation interval. Greatest rates of genetic progress are obtained with high heritability traits, large selection differentials and a short generation interval (Table 3). However, for traits of low heritability larger selection differentials and accurate genetic evaluations can be exploited to achieve substantial rates of genetic progress.

Table 3 Achieving Maximum Rates of Genetic Progress

$$\text{Maximum Genetic Progress} = \frac{\text{high } h^2 \text{ x large selection differential *}}{\text{short generation interval *}}$$

* *Selection differential and to a lesser extent, generation interval, can be changed by the producer, h^2 cannot.*

- If the h^2 of the trait is low, the selection differential must be increased and the generation interval shortened to achieve substantial rates of genetic progress.

CORRELATION

Measures the amount of relationship between two traits. A correlation can range from -1.0 to +1.0. A relationship can be caused by the same genes influencing two different traits (genetic correlation) or by one aspect of the environment affecting two traits (environmental correlation). Traits can be positively or negatively correlated. If positively correlated, then increases in one trait will cause an increase in the other. In the case of a negative correlation an increase in one trait will cause a decline in the other. Examples of positive and negative correlations are given in Table 4. Relationships between traits should be considered when determining what traits and how many will be selected for.

Table 4 Examples of Positive (+) and Negative (-) Correlations Between Traits

Positive Correlation

↑ Backfat thickness – ↑ Feed conversion

- fatter animals tend to require more feed per pound of gain (less efficient feed converters).

Negative Correlation

↑ Growth rate – ↓ Feed conversion

- faster-growing animals tend to require less feed per pound of gain (more efficient feed converters).

ESTIMATED BREEDING VALUE (EBV)

Estimates the true genetic merit (worth) of an animal. An EBV will give an indication of what an animal is capable of passing on to its offspring genetically. An interpretation of EBV's is given in Table 5.

Figure 5 Explanation of EBV's and the EBV Index

Yorkshire Boar:

EBV - Backfat	EBV-Days to 90Kg	EBV-Index
- 1.8	- 2.7	142

This boar is **genetically** 1.8 mm leaner and 2.7 days faster-growing than the average Yorkshire boar in Ontario. His EBV Index is 142, 42 points above average (100 is average). The EBV Index combines both traits and weights them so that a change of 1 mm in backfat has approximately the same value as a change of 4 days in growth rate.

REPEATABILITY (r^2)

Describes the relationship between the true genetic or breeding value of an animal and its estimated breeding value. It is measured on the same scale as heritability, that is, it ranges from 0 to 100%. Repeatability is used to describe the accuracy of an EBV. For example, EBV's based on large numbers of progeny in many different herds are more accurate (repeatable) than those based on fewer progeny in only a few herds.

CROSSBREEDING

A system of mating animals of different breeds or combinations of breeds. Crossing of different breeds results in heterosis for some economically important traits.

HETEROSIS (Hybrid Vigour)

The superiority of the crossbred animal over the average of the parental breeds. Heterosis is usually greatest for traits of low heritability, such as sow productivity. Highly heritable traits generally show little heterosis.

INDEX

A formula based on selection for more than one trait which is designed to determine combined worth. Each trait in the index is given a weight based on its economic importance and its ability to respond to genetic selection. The ROP Index appropriately weights backfat thickness and days to 90 kg in order to increase overall economic improvement.

FULL-SIB

Animals with the same parents (littermates and full brothers and sisters from previous and future matings).

HALF-SIB

Animals with only one parent in common (half brothers and sisters). Paternal half-sibs have the same father; maternal half-sibs the same mother.

Development of an effective breeding program requires careful planning and dedication. Following are a few points to consider:

1. Develop a breeding goal with these points in mind:
   - traits to select for should have the potential to respond genetically and be economically important.
   - selection goals should be consistent and practiced evenly over time.
   - sufficient numbers of animals should be tested to allow adequate intensity of selection.
   - the selection mechanism should be simple.
   - herd size of a given breed or line should be sufficiently large to allow effective selection.
2. Collect data (performance test, sow productivity) and keep accurate records for selection and culling.
3. Commit yourself to your breeding goal.
4. Evaluate your breeding program regularly and monitor change to ensure genetic progress.

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